

TITLE OF THE INVENTION  
EXPOSURE APPARATUS, MAINTENANCE METHOD THEREFOR,  
SEMICONDUCTOR DEVICE MANUFACTURING METHOD, AND  
SEMICONDUCTOR MANUFACTURING FACTORY

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FIELD OF THE INVENTION

The present invention relates to an exposure apparatus used for photolithography in the manufacturing process of a semiconductor integrated circuit, liquid crystal display element, or the like, a maintenance method therefor, a semiconductor device manufacturing method, and a semiconductor manufacturing factory.

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BACKGROUND OF THE INVENTION

Fig. 13 is a flow chart showing the focus algorithm of a stationary exposure apparatus (stepper). A focus on a wafer as a substrate loaded onto a wafer stage is measured at a focus measurement shot out of several representative shots on the wafer (step 1301). A global approximate plane as a linear plane which represents the wafer surface is calculated by, e.g., least-square approximation from the obtained focus measurement data (step 1302). The target value of the wafer stage in the Z direction when the wafer stage is driven to locate the wafer surface on the global approximate plane is called a global focus target value,

and its target values in the  $\omega_x$  and  $\omega_y$  directions at this time are called global tilt target values.

Shots subjected to global focus/tilt measurement simultaneously undergo alignment measurement at, e.g.,  
5 alignment mark positions (1401x, 1401y, 1402x, 1402y, 1403x, 1403y, 1404x, and 1404y) of shots hatched on the wafer in Fig. 14. Fig. 14 is a view showing a shot position on the wafer subjected to global focus measurement. To increase the precision of the measured  
10 global tilt amount and that of the rotation angle in the  $\theta$  direction in global alignment, measurement spans in the X and Y directions are preferably widened, and the shots are desirably near the periphery of the wafer.

In Fig. 13, an X-Y stage moves stepwise to a  
15 target exposure shot position (step 1303). At the same time, a Z tilt wafer stage moves to a focus/tilt position in the exposure shot that is estimated from the global approximate plane (step 1304). Upon the completion of movement, a focus is measured again at  
20 the exposure position (step 1305). Focusing driving (step 1307) and focus measurement (step 1305) are repeated until the focus tolerance check passes (step 1306). In focus measurement (step 1305), a focus sensor measures focus measurement points in a plurality  
25 of exposure shots as shown in Fig. 15, and a linear approximate plane obtained from the measurement values is set as a wafer surface. Wafer stage target values

for performing focusing so as to locate the wafer surface on an image plane are sequentially calculated. Fig. 15 is a view showing the layout of focus measurement points within an exposure shot in the stationary exposure apparatus.

In Fig. 15, ch1 to ch5 are focus measurement points, one measurement point is formed from five marks (1501a to 1501e), and the average of the measurement values of the respective marks in the focus direction is used as focus measurement data for each point (ch1 to ch5). An exposure shot 1502 is measured at a plurality of focus measurement points (ch1 to ch5). For example, when the focus measurement value of ch5 greatly deviates from those of ch1 to ch4, the wafer surface is regarded to have a defect and is not exposed (case A). Alternatively, as for a greatly different measurement point, its measurement value is not used as focus measurement data, and an approximate plane is calculated from the remaining focus measurement points (case B).

If the focus tolerant passes, the flow waits for convergence of residual vibrations in the X and Y directions generated in the step of focus driving/Abbe correction driving (step 1307) in Fig. 13 (step 1308), and exposure starts (step 1309). In step 1310, whether all the shots have undergone the exposure sequence is checked. If N in step 1310, the focus algorithm (steps

1303 to 1310) is repeated by using the first measured global approximate plane data (step 1302).

The surface of a process wafer may be corrugated by about 5 to 10 [ $\mu$ m] during the manufacturing process.

5 When such a wafer is to be exposed, the exposure sequence is interrupted at the shot of a corrugated portion, and the shot does not allow exposure in a prior art like case A. In this case, in the prior art, the exposure sequence shifts to process the next shot  
10 without exposing the shot of a projecting portion. At the unexposed shot, the residual resist amount is larger than that at peripheral shots in the resist developing process, and may adversely affect a resist image at the peripheral shots.

15 If a focus error is generated by a wafer, the job aborts in the prior art, and the exposure sequence enters a manual operation mode where the operator determines processing of the defective shot.

If a focusing error is generated under the  
20 influence of dust or the like attached to a wafer chuck, the chuck must be cleaned to remove its contamination. In a prior art like case B, however, no focusing error is detected, and the contamination of the wafer chuck must be estimated from the wafer developing result.

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#### SUMMARY OF THE INVENTION

The present invention has been made to overcome

the conventional drawbacks, and has as its object to provide an exposure apparatus which minimizes the influence of a defective shot on peripheral shots, reduces defective shots, reduces misoperations caused by the operator, and detects the contamination of a wafer chuck within the exposure process, a maintenance method therefor, a semiconductor device manufacturing method, and a semiconductor manufacturing factory.

To overcome the above drawbacks, according to the first aspect of the present invention, there is provided an exposure apparatus which has a stage for aligning a substrate surface to an imaging plane on the basis of a detection signal from a focus sensor, moves the substrate by the stage, transfers a projection pattern, and exposes the substrate, comprising a controller for, when an exposure shot region on the substrate cannot converge to a predetermined precision, determining the exposure shot as an error, and controlling the stage so as to move the substrate to a predetermined position upon determination of the error, and an exposure unit for forcibly transferring the projection pattern onto the substrate at the predetermined position in the exposure shot and exposing the substrate.

According to the second aspect of the present invention, there is provided an exposure apparatus for transferring a projection pattern onto a substrate and

exposing the substrate while scanning the substrate by  
a stage, comprising a controller for, when an exposure  
shot region on the substrate cannot converge during  
scan to a predetermined focus precision or leveling  
5 precision, a predetermined two-dimensional sync control  
precision, or a predetermined exposure amount control  
precision, determining the exposure shot as an error,  
and controlling the stage so as to move the substrate  
to a predetermined position upon determination of the  
10 error, and an exposure unit for forcibly transferring  
the projection pattern onto the substrate at the  
predetermined position in the exposure shot and  
exposing the substrate.

According to the third aspect of the present  
15 invention, there is provided an exposure apparatus for  
transferring a projection pattern onto a substrate and  
exposing the substrate while scanning the substrate,  
comprising a controller for, when an exposure shot  
region cannot converge to a predetermined focus  
20 precision during scan, determining the exposure shot as  
an error, and controlling a shot beam from an exposure  
light source upon determination of the error.

According to the present invention, there is  
provided a semiconductor device manufacturing method  
25 comprising the steps of installing manufacturing  
apparatuses for various processes including any one of  
the above-described exposure apparatuses in a

semiconductor manufacturing factory, and manufacturing a semiconductor device by using the manufacturing apparatuses in a plurality of processes.

According to the present invention, there is  
5 provided a semiconductor manufacturing factory comprising manufacturing apparatuses for various processes including any one of the above-described exposure apparatuses, a local area network for connecting the manufacturing apparatuses, and a gateway  
10 which allows the local area network to access an external network outside the factory, wherein information about at least one of the manufacturing apparatuses can be communicated.

According to the present invention, there is  
15 provided a maintenance method for any one of the above-described exposure apparatuses that is installed in a semiconductor manufacturing factory, comprising the steps of causing a vendor or user of the exposure apparatus to provide a maintenance database connected  
20 to an external network of the semiconductor manufacturing factory, authorizing access from the semiconductor manufacturing factory to the maintenance database via the external network, and transmitting maintenance information accumulated in the maintenance  
25 database to the semiconductor manufacturing factory via the external network.

According to the fourth aspect of the present

invention, any one of the above-described exposure apparatuses further comprises a display, a network interface, and a computer for executing network software, and maintenance information of the exposure apparatus can be communicated via the computer network.

Other objects and advantages besides those discussed above shall be apparent to those skilled in the art from the description of a preferred embodiment of the invention which follows. In the description, reference is made to accompanying drawings, which form apart thereof, and which illustrate an example of the invention. Such example, however, is not exhaustive of the various embodiments of the invention, and therefore reference is made to the claims which follow the description for determining the scope of the invention.

#### BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a block diagram showing the hardware arrangement of an exposure apparatus according to an embodiment of the present invention;

Fig. 2 is a view showing a state when a wafer surface is driven to a global tilt plane;

Fig. 3 is a view showing the positional relationship between an exposure slit and focus measurement points on the imaging plane in the exposure apparatus according to the embodiment of the present invention;



Fig. 4 is a flow chart showing an example of an exposure sequence in the exposure apparatus according to the embodiment of the present invention;

Fig. 5 is a view showing the layout of focus measurement positions and an exposure slit within an exposure shot;

Fig. 6 is a view showing an example of operation buttons displayed upon generation of a focus control error in the exposure apparatus according to the embodiment of the present invention;

Fig. 7 is a view showing an example of the user interface window of the exposure apparatus according to the embodiment of the present invention;

Fig. 8 is a view showing the concept of a semiconductor device production system including the exposure apparatus according to the embodiment of the present invention when viewed from a given angle;

Fig. 9 is a view showing the concept of the semiconductor device production system including the exposure apparatus according to the embodiment of the present invention when viewed from another given angle;

Fig. 10 is a view showing an example of a user interface in the semiconductor device production system including the exposure apparatus according to the embodiment of the present invention;

Fig. 11 is a flow chart for explaining the flow of a device manufacturing process by the exposure

apparatus according to the embodiment of the present invention;

Fig. 12 is a flow chart for explaining a wafer process by the exposure apparatus according to the embodiment of the present invention;

Fig. 13 is a flow chart showing the focus (exposure) algorithm of a conventional stationary exposure apparatus;

Fig. 14 is a view showing a shot position on a wafer subjected to global focus measurement in the conventional stationary exposure apparatus; and

Fig. 15 is a view showing the layout of focus measurement points within an exposure shot in the conventional stationary exposure apparatus.

#### DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Preferred embodiments of the present invention will be described in detail below with reference to the accompanying drawings.

#### [Exposure Apparatus]

Fig. 1 shows the hardware arrangement of an exposure apparatus according to an embodiment of the present invention. A reticle 109 set on a reticle stage 108 is scanned at a constant speed in the direction indicated by an arrow in FIG. 1 under the control of a reticle stage controller 103. Part of a pattern image on the reticle 109 serving as a master is

horizontally reversed by a projection optical system 110 and projected onto an imaging plane on a focus stage 112. The focus stage 112 is mounted on an alignment stage 113 and performs alignment in the Z direction and tilt directions ( $\omega_x$  and  $\omega_y$ ). The alignment stage 113 is drivable in the X, Y, and  $\theta$  directions and is scanned at a constant speed by a wafer stage controller 101 in the direction indicated by an arrow in Fig. 1, i.e., direction opposite to the driving direction of the reticle stage 108 during scan exposure. The ratio of the scan speeds of the alignment stage 113 and reticle stage 108 is determined from the projection magnification of the projection optical system 110 and the scaling ratio of a transferred image.

A focus measurement sensor 111 as a focus detection mechanism is fixed to an apparatus housing which contains the projection optical system 110, and measures the focus direction of a wafer 120 serving as a substrate set on the focus stage 112. A signal obtained by the focus measurement sensor 111 is converted into a focus measurement value 105 of an expression corresponding to the coordinate system of the wafer stage by a focus signal processing unit 102, and the focus measurement value 105 is transferred to the wafer stage controller 101. In shot exposure, the wafer stage controller 101 controls the manipulation

quantity of the focus stage 112 so as to allow the surface of the wafer 120 to reach a focus target value corresponding to an imaging plane included in the argument of an exposure command 107 transferred from a  
5 main sequence controller 104 in advance.

Reference numeral 115 denotes an illumination optical system which disperses the coherence of an exposure laser beam from a pulse laser source 116 and shapes the light quantity distribution of a slit shape.  
10 The wafer stage controller 101 controls in real time the emission start and stop timings of a pulse laser by using an emission enable signal 117 in accordance with the stage position during scan.

The main sequence controller 104 designates to  
15 the alignment stage 113 by using the exposure command 107 a scan driving target value included in a command issued for each shot, and designates to the focus stage 112 a focus target value to an imaging plane and an initial focus target value (to be referred to as a  
20 neighboring focus target value hereinafter) for performing preset before scan exposure. The main sequence controller 104 sends a pulse energy/wavelength command signal 118 to the pulse laser source 116 for each shot or every predetermined timing. After one  
25 shot is exposed, a focus control target value 106 of the focus stage 112 calculated by the wafer stage controller 101 is sent back to the main sequence

controller 104 in order to achieve alignment in the focus direction of the shot. This data is used as the neighboring focus target value of a subsequent shot. The neighboring focus target value is used as the  
5 target value of the focus/tilt axis of the wafer stage in executing forced exposure (to be described with reference to a flow chart) when the wafer 120 is so corrugated as to generate a focusing error at the next exposure shot. When the focusing error shot is the  
10 first exposure shot on the wafer 120, a global tilt target value (to be described later) is used as the target value of the focus/tilt axis of the wafer stage in executing forced exposure.

Fig. 2 is a view showing a state after the wafer  
15 stage is driven to a position where the global approximate plane is measured as  $(Z, \omega x, \omega y) = (0, 0, 0)$  when the next global focus/tilt measurement is similarly done by using a value obtained by global focus/tilt measurement. In Fig. 2, the same reference  
20 numerals as in Fig. 1 denote the same parts.

The surface of the wafer 120 is parallel to a driving locus (wafer stage traveling surface 201) with a constant target value in the Z direction of the wafer stage. As far as the surface of the wafer 120 is  
25 ideally parallel, no defocus occurs below an exposure slit in scan exposure in this state. In practice, however, local corrugations exist on the surface of the

wafer 120 to a considerable amount with respect to the depth of focus. Thus, a focus is measured during exposure, and a laser must be focused not to defocus the surface of the wafer 120 immediately below the slit.

5 This amount is 3 to 4 [ $\mu\text{m}$ ] at maximum with respect to the global tilt plane on a general single-side-polished wafer 120, though the amount changes depending on the surface polishing step or process of the wafer 120. To the contrary, the focus control precision assigned to

10 focus control in exposure is about 0.1 [ $\mu\text{m}$ ] according to the 0.15  $\mu\text{mL/S}$  rule.

Fig. 3 shows the positional relationship between an exposure slit and focus measurement points on the imaging plane in the exposure apparatus according to

15 the embodiment of the present invention. When the alignment stage 113 (Fig. 2) scans the wafer in the direction indicated by arrow 1, focus measurement points a, b, and c are used, and when the alignment stage 113 scans the wafer in the direction indicated by

20 arrow 2, focus measurement points A, B, and C are used. A focus measurement point S is also set at the center of the shot. A focus is measured at combined points (a, b, c, S) and (A, B, C, S) during one cycle of a plurality of focus measurement events during scan in

25 order to confirm a convergence result in the focus direction during exposure. In the focus measurement cycle, an obtained focus measurement value is

determined as a focus convergence error under the following conditions (when convergence within a given focus alignment precision fails).

(i) Variations in measurement values from the average of measurement values at a, b, and c exceed a prescribed allowable amount.

(ii) An absolute tilt amount calculated from  $\omega_y = (a-c)/L$  exceeds a prescribed allowable amount.

(iii) An absolute focus amount calculated from  $Z = (a+b+c)/3$  exceeds a prescribed allowable amount.

(iv) The differences between Z and  $\omega_y$  obtained by previous focus measurement, and Z and  $\omega_y$  obtained by current focus measurement exceed prescribed allowable amounts, respectively.

The focus convergence error occurs in the following two cases (A) and (B).

(A) A convergence error (non-exposure focus error) before exposure starts because an exposure shot is measured for a focus measurement point but the exposure slit does not enter the exposure area.

(B) A convergence error (exposure abort focus error) when the exposure slit enters the exposure area and exposure already starts.

In case (A), the emission enable signal 117 in Fig. 1 is immediately disabled to stop emission of the pulse laser source 116 (shield an exposure beam). In a slow light source system such as a mercury lamp light

source, a high-speed shutter may be arranged in the illumination optical system 115 to shield an exposure beam.

In case (B), exposure can be immediately stopped, like case (A), which produces an exposed portion and unexposed portion within a shot. When exposure intermittently aborts within a shot, a portion where exposure has aborted is stored in the wafer stage controller 101 in Fig. 1, and emission of the illumination optical system 115 starts in retry at the portion where exposure has aborted. In this embodiment, exposure does not abort in such a case for the sake of descriptive simplicity, and exposure continues to the final portion left in the shot region by forcibly exposing the shot. At this time, exposure must continue without any focus measurement value. The values  $Z$  and  $\omega_y$  (focus and tilt positions) at the final focus measurement position measured normally are most desirably used. A global focus measurement value or the neighboring focus value of a previous shot may be used.

Also in a stationary exposure apparatus, a focus control error occurs when, for example, the focus tolerance check does not pass (step 1306) even if the convergence loop for performing focus measurement (step 1305), focus tolerance check (step 1306), and focus driving/Abbe correction driving (step 1307) is repeated



a predetermined number of times in the flow chart of the prior art in Fig. 13, or when the variance of measurement values at respective measurement points from a linear approximate plane calculated between  
5 focus measurement points in a shot shown in Fig. 15 exceeds a prescribed amount.

Fig. 4 shows an example of an exposure sequence in the exposure apparatus according to the embodiment of the present invention. A command to a light source  
10 upon generation of a focus control (convergence) error is determined, and emission of the exposure light source is controlled in real time by the wafer stage controller 101 (Fig. 1). The wafer stage controller 101 transmits for each shot to the main sequence  
15 controller 104 (Fig. 1) a focus control error status and information representing whether a shot has been exposed.

The flow chart in Fig. 4 shows the sequence of the main sequence controller 104 performed based on  
20 information from the wafer stage controller 101 that is obtained for each exposure shot. Alignment of the wafer 120 on the wafer stage is measured by an alignment scope 114 before the exposure sequence. After a driving target value for each exposure shot is  
25 determined, the main sequence controller 104 enters this sequence.

In Fig. 4, if an exposure command 401 for each

shot is received, the wafer stage and reticle stage temporarily skip to a pre-scan start point, and scan starts. During scan, a focus measurement unit sequentially measures a focus from 507 to 501 in Fig. 5, and calculates the target value of the wafer stage from the measurement results. Fig. 5 is a view showing the layout of focus measurement positions and an exposure slit 301 (Fig. 3) within an exposure shot 508.

Processing when a focus control error occurs will be explained with reference to Fig. 4.

In Fig. 4, the focus measurement points a, b, and c (Fig. 5) are set before the exposure slit 301 (Fig. 5) in the scan direction, so that a focus control error (focus convergence error) 402 may occur before or during exposure. At this time, the exposure apparatus immediately displays, e.g., a message window on a user interface to display an error message (403).

For a focus convergence error, whether the target shot has already been exposed is determined (404), and if the target shot has already been exposed, the flow shifts to a sequence 405 of determining whether the current mode is an automatic continuation mode. If the focus control error 402 occurs, whether the exposure slit 301 (Fig. 5) enters the exposure area and exposure starts is checked. If exposure does not start, processing of inhibiting emission of the pulse light source is immediately executed; if exposure starts, the

target shot is completely exposed without stopping  
emission of the light source. If the target shot is  
not exposed or a focus control error is generated by a  
factor such as a disturbance from a floor, retry of the  
5 same exposure may succeed.

In a sequence 406, whether an automatic operation  
mode is set is determined. If Y in 406, the shot  
(focus convergence error shot) is exposed under the  
same conditions. In 407, whether a focus control error  
10 occurs even upon retry in the same shot is checked. If  
retry fails once, a forced exposure sequence 417 is  
executed. In forced exposure 417, not a value obtained  
by measuring the wafer surface, but a global focus/tilt  
target value which is a target value independent of a  
15 focus measurement sensor value, or the focus/tilt  
target value of the wafer stage obtained during the  
exposure time of the final portion of the previously  
exposed shot is adopted as a fixed target value during  
scan. In automatic forced exposure 417, even if the  
20 reliability of the focus measurement value degrades  
owing to, e.g., a fault of the focus measurement system,  
the exposure sequence continues with an improper  
focus/tilt target value. Forced exposure 417 should  
therefore be limited within a finite number of  
25 successive shots. In a sequence 413, if the result of  
counting the number of successive operations of forced  
exposure 417 exceeds five shots, the job stops even in

the automatic continuation mode (sequence stop 414).

If the job stops, buttons as shown in Fig. 6 are displayed on the user interface in order to cause the operator to select (determine) subsequence processing, and the flow waits for operator designation (sequence 5 415). Fig. 6 is a view showing an example of operation buttons displayed upon generation of a focus control error in the embodiment of the present invention. In Figs. 4 and 6, a CONT (Continue) button is for 10 designating continuation of processing. If the operator clicks the CONT button, exposure of a shot suffering a focus convergence error is skipped, and the flow advances to the exposure sequence of the next shot (shot B scan exposure command 416). An ABORT (Abort) 15 button means the end of the exposure job (411), and is for aborting the job in progress and recovering all wafers in process. An RW (Reject Wafer) button is for aborting the exposure sequence of only the current exposure target wafer and recovering the wafer (412). 20 If N in 406, the job immediately aborts (sequence stop 408), and the flow waits for a user button input shown in Fig. 6 (409). Choices in this case are a sequence 415, a RETRY (Retry) button for performing retry processing for a shot suffering a focus control error, 25 and a FORCE (Force) button for performing forced exposure processing 410 when focusing fails.

When a focus control error is generated by the

wafer stage controller 101 (Fig. 1) and part of the target shot has already been exposed, the shot has already been exposed in a defocused state. If Y in the sequence 405 (automatic continuation mode), a check in  
5 the sequence 413 is performed, and the flow shifts to processing 416 of the next shot; if N, the exposure sequence aborts (sequence stop 414), and the flow waits for a user button input (415).

The position of the shot suffering the focus  
10 control error is stored in the main sequence controller 104 (Fig. 1). The generation factors of focus control errors are classified into (A) defects of the wafer surface state, (B) contamination of the wafer chuck surface by a resist peeled from a wafer, (C) vibrations  
15 by a disturbance from a floor, and (D) apparatus faults. Among them all, factor (B) can be separated from the cause because focus control errors occur at the same shot position commonly to respective wafers. This embodiment has a function of storing a shot position  
20 where focus control errors occur on respective wafers, regarding the focus control errors generated at the same shot position as errors generated by contamination of the wafer chuck, and aborting the job. When  
25 contamination of the wafer chuck is detected by this function, the wafer chuck can be exchanged or cleaned to rapidly determine the factor of a focus control error and increase the shot yield.

As for a function of comparing the number of  
forcibly exposed shots in the automatic continuation  
modes 405, 406, and 413 with a predetermined number of  
shots (five shots), selection of  
5 execution/non-execution of the automatic continuation  
mode and designation of a predetermined number of shots  
can be achieved via a man-machine interface connected  
to the main sequence controller 104 (Fig. 1). By  
applying the present invention, it can also be easily  
10 realized to record the total number of shots subjected  
to forced exposure processing for each wafer or lot and  
transmit the total number to an on-line host machine.  
When, for example, contamination of the wafer chuck is  
identified, the operator can be warned of this via the  
15 man-machine interface.

Further, the present invention can be applied as  
error processing when the sync control precision in the  
alignment direction or the total exposure amount in the  
exposure slit that is calculated from a monitored  
20 illuminance exceeds a preset allowable amount. Whether  
sync control or exposure amount control achieves a  
desired precision can be determined only after scan  
exposure starts. If emission of the exposure light  
source stops because the desired precision cannot be  
25 achieved, a partially unexposed portion is formed and  
adversely affects peripheral shots which have normally  
been exposed in developing the resist. Hence, the

target shot is preferably completely exposed by forced exposure without stopping exposure when the sync control precision or exposure amount control precision deviates from a standard precision during exposure (to be referred to as a standard precision short error hereinafter). The next shot is normally processed with high possibility for a standard precision short error generated by floor vibrations, a local factor of the wafer 120 (Fig. 1), or misfire of the pulse laser source 116 (Fig. 1) (omission of emission pulses). In many cases, a standard precision short error generated by the service life of the pulse laser source 116 or a fault of the exposure apparatus occurs at successive shots. Thus, the algorithm of the automatic continuation mode can be similarly applied to monitoring of the exposure amount control precision and sync control precision. The job can continue without stopping the apparatus for an inevitable standard precision short error caused by a local factor, resulting in high apparatus availability. A standard precision short error generated by an apparatus fault or the like can be determined to stop the sequence with a minimum damage by monitoring whether the error is generated at successive shots. As another method of stopping the sequence owing to repeated standard precision short errors, the errors are identified based on the total number of generated errors or the number

of generated errors (generation rate) within a predetermined number of exposure shots, other than monitoring of errors at successive shots.

As for the sync precision specification, exposure precision specification, and focus/leveling precision specification of the apparatus, the guaranteed performance is generally defined by sigma. The present invention is effective as a means for determining whether the standard performance of the apparatus is actually achieved and monitoring the standard performance during the operation of the apparatus. This is because an exposure shot which does not probabilistically meet the standard precision necessarily exists, and if an error is determined by giving attention to the exposure result of a single shot, the sequence may stop even during normal operation in terms of the standard definition (sigma).

A stationary exposure apparatus adopts a sequence in which exposure starts after the focus convergence is achieved in advance. When a focus convergence error occurs in the focus convergence process, exposure can be stopped before it starts by canceling emission of a light source or keeping the shutter closed. The stationary exposure apparatus does not require processing 404 of determining whether part of a shot has been exposed upon generation of a focus convergence error in Fig. 4, and processing 405 of determining



whether the exposure apparatus operates in the automatic continuation mode. The remaining processes can be similarly applied as the focus control error processing step in the stationary exposure apparatus.

5        Fig. 7 is a view showing an example of the user interface window of the exposure apparatus according to the embodiment of the present invention. Reference numeral 740 denotes a window for displaying a sequence in progress; 741, a window for displaying an error and  
10        warning generated during execution of a job; and 742, a wafer shape to be exposed, on which exposure shots 701 to 730 are hatched upon the completion of exposure. Of the exposure shots 701 to 730, the exposure shots 705 and 706 represent shots suffering focus control errors  
15        and are hatched in a different color to allow the operator to discriminate them from normally exposed shots. Reference numeral 743 denotes an operation button. A permitted operation changes depending on a sequence which executes a job, and a menu displayed on  
20        the button 743 changes depending on the operation. If a re-exposure enable focus convergence error occurs in a mode other than the automatic continuation mode, operation buttons as shown in Fig. 6 are displayed to wait for operator designation.

25        [Embodiment of Semiconductor Production System]

          A production system for a semiconductor device (semiconductor chip such as an IC or LSI, liquid

crystal panel, CCD, thin-film magnetic head,  
micromachine, or the like) using the exposure apparatus  
will be exemplified. A trouble remedy or periodic  
maintenance of a manufacturing apparatus installed in a  
5 semiconductor manufacturing factory, or maintenance  
service such as software distribution is performed by  
using, e.g., a computer network outside the  
manufacturing factory.

Fig. 8 shows the overall system cut out at a  
10 given angle. In Fig. 8, reference numeral 801 denotes  
a business office of a vendor (apparatus supply  
manufacturer) which provides a semiconductor device  
manufacturing apparatus. Assumed examples of the  
manufacturing apparatus are semiconductor manufacturing  
15 apparatuses for various processes used in a  
semiconductor manufacturing factory, such as  
pre-process apparatuses (lithography apparatus  
including an exposure apparatus, resist processing  
apparatus, and etching apparatus, annealing apparatus,  
20 film formation apparatus, planarization apparatus, and  
the like) and post-process apparatuses (assembly  
apparatus, inspection apparatus, and the like). The  
business office 801 comprises a host management system  
808 for providing a maintenance database for the  
25 manufacturing apparatus, a plurality of operation  
terminal computers 810, and a LAN (Local Area Network)  
809 which connects the host management system 808 and

computers 810 to build an intranet. The host  
management system 808 has a gateway for connecting the  
LAN 809 to Internet 805 as an external network of the  
business office, and a security function for limiting  
5 external accesses.

Reference numerals 802 to 804 denote  
manufacturing factories of the semiconductor  
manufacturer as users of manufacturing apparatuses.  
The manufacturing factories 802 to 804 may belong to  
10 different manufacturers or the same manufacturer  
(pre-process factory, post-process factory, and the  
like). Each of the factories 802 to 804 is equipped  
with a plurality of manufacturing apparatuses 806, a  
LAN (Local Area Network) 811 which connects these  
15 apparatuses 806 to construct an intranet, and a host  
management system 807 serving as a monitoring apparatus  
for monitoring the operation status of each  
manufacturing apparatus 806. The host management  
system 807 in each of the factories 802 to 804 has a  
20 gateway for connecting the LAN 811 in the factory to  
the Internet 805 as an external network of the factory.  
Each factory can access the host management system 808  
of the vendor 801 from the LAN 811 via the Internet 805.  
The security function of the host management system 808  
25 authorizes access of only a limited user. More  
specifically, the factory notifies the vendor via the  
Internet 805 of status information (e.g., the symptom

of a manufacturing apparatus in trouble) representing the operation status of each manufacturing apparatus 806, and receives response information (e.g., information designating a remedy against the trouble, or remedy software or data) corresponding to the notification, or maintenance information such as the latest software or help information. Data communication between the factories 802 to 804 and the vendor 801 and data communication via the LAN 811 in each factory adopt a communication protocol (TCP/IP) generally used in the Internet. Instead of using the Internet as an external network of the factory, a dedicated network (e.g., ISDN) having high security which inhibits access of a third party can be adopted. Also the user may construct a database in addition to the one provided by the vendor and set the database on an external network, and the host management system may authorize access to the database from a plurality of user factories.

Fig. 9 is a view showing the concept of the overall system of this embodiment that is cut out at a different angle from Fig. 8. In the above example, a plurality of user factories having manufacturing apparatuses and the management system of the manufacturing apparatus vendor are connected via an external network, and production management of each factory or information of at least one manufacturing

apparatus is communicated via the external network. In the example of Fig. 9, a factory having manufacturing apparatuses of a plurality of vendors and the management systems of the vendors for these manufacturing apparatuses are connected via the external network of the factory, and maintenance information of each manufacturing apparatus is communicated. In Fig. 9, reference numeral 901 denotes a manufacturing factory of a manufacturing apparatus user (semiconductor device manufacturer) where manufacturing apparatuses for various processes, e.g., an exposure apparatus 902, resist processing apparatus 903, and film formation apparatus 904 are installed in the manufacturing line of the factory. Fig. 9 shows only one manufacturing factory 901, but a plurality of factories are networked in practice. The respective apparatuses in the factory are connected to a LAN 960 to build an intranet, and a host management system 905 manages the operation of the manufacturing line. The business offices of vendors (apparatus supply manufacturers) such as an exposure apparatus manufacturer 910, resist processing apparatus manufacturer 920, and film formation apparatus manufacturer 930 comprise host management systems 911, 921, and 931 for executing remote maintenance for the supplied apparatuses. Each host management system has a maintenance database and a gateway for an external

network, as described above. The host management system 905 for managing the apparatuses in the manufacturing factory of the user, and the management systems 911, 921, and 931 of the vendors for the  
5 respective apparatuses are connected via the Internet or dedicated network serving as an external network 900. If a trouble occurs in any one of a series of manufacturing apparatuses along the manufacturing line in this system, the operation of the manufacturing line  
10 stops. This trouble can be quickly solved by remote maintenance from the vendor of the apparatus in trouble via the Internet 900. This can minimize the stop of the manufacturing line.

Each manufacturing apparatus in the semiconductor  
15 manufacturing factory comprises a display, a network interface, and a computer for executing network access software and apparatus operating software which are stored in a storage device. The storage device is a built-in memory, hard disk, or network file server.  
20 The network access software includes a dedicated or general-purpose web browser, and provides a user interface having a window as shown in Fig. 10 on the display. While referring to this window, the operator who manages manufacturing apparatuses in each factory  
25 inputs, in input items on the windows, pieces of information such as the type of manufacturing apparatus 1001, serial number 1002, subject of trouble 1003,

occurrence date 1004, degree of urgency 1005, symptom 1006, remedy 1007, and progress 1008. The pieces of input information are transmitted to the maintenance database via the Internet, and appropriate maintenance information is sent back from the maintenance database and displayed on the display. The user interface provided by the web browser realizes hyperlink functions 1010, 1011, and 1012, as shown in Fig. 10. This allows the operator to access detailed information of each item, receive the latest-version software to be used for a manufacturing apparatus from a software library provided by a vendor, and receive an operation guide (help information) as a reference for the operator in the factory. Maintenance information provided by the maintenance database also includes information concerning the present invention described above. The software library also provides the latest software for implementing the present invention.

A semiconductor device manufacturing process using the above-described production system will be explained. Fig. 11 shows the flow of the whole manufacturing process of the semiconductor device. In step 1 (circuit design), a semiconductor device circuit is designed. In step 2 (mask formation), a mask having the designed circuit pattern is formed. In step 3 (wafer manufacture), a wafer is manufactured by using a material such as silicon. In step 4 (wafer process)

called a pre-process, an actual circuit is formed on the wafer by lithography using a prepared mask and the wafer. Step 5 (assembly) called a post-process is the step of forming a semiconductor chip by using the wafer manufactured in step 4, and includes an assembly process (dicing and bonding) and packaging process (chip encapsulation). In step 6 (inspection), inspections such as the operation confirmation test and durability test of the semiconductor device manufactured in step 5 are conducted. After these steps, the semiconductor device is completed and shipped (step 7). For example, the pre-process and post-process are performed in separate dedicated factories, and maintenance is done for each of the factories by the above-described remote maintenance system. Information for production management and apparatus maintenance is communicated between the pre-process factory and the post-process factory via the Internet or dedicated network.

Fig. 12 shows the detailed flow of the wafer process. In step 11 (oxidation), the wafer surface is oxidized. In step 12 (CVD), an insulating film is formed on the wafer surface. In step 13 (electrode formation), an electrode is formed on the wafer by vapor deposition. In step 14 (ion implantation), ions are implanted in the wafer. In step 15 (resist processing), a photosensitive agent is applied to the



wafer. In step 16 (exposure), the above-mentioned exposure apparatus exposes the wafer to the circuit pattern of a mask. In step 17 (developing), the exposed wafer is developed. In step 18 (etching), the resist is etched except for the developed resist image. In step 19 (resist removal), an unnecessary resist after etching is removed. These steps are repeated to form multiple circuit patterns on the wafer. A manufacturing apparatus used in each step undergoes maintenance by the remote maintenance system, which prevents a trouble in advance. Even if a trouble occurs, the manufacturing apparatus can be quickly recovered. The productivity of the semiconductor device can be increased in comparison with the prior art.

The above-described embodiment enables forced exposure when a wafer flatness defect is generated by the process. The influence on peripheral shots exposed normally in etching can be minimized to increase the wafer yield.

The above-described embodiment comprises a function of storing the generation position of a focus control error between the wafers when a wafer flatness defect is generated by the chuck. In addition to the above effects, contamination of the wafer chuck can quickly be found.

The above-described embodiment comprises a

function of stopping exposure if scan exposure does not start and retrying exposure when a focus control error is generated under the influence of a disturbance from a floor. The ratio of erroneous exposure shots can be  
5 reduced to increase yield.

Moreover, the above-described embodiment comprises a function of automatically determining retry or forced exposure. The stop time of the apparatus due to a wait for operator determination can be minimized  
10 to increase the apparatus availability.

The present invention is not limited to the above embodiments and various changes and modifications can be made within the spirit and scope of the present invention. Therefore, to apprise the public of the  
15 scope of the present invention the following claims are made.